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# THESIS

## EVALUATION OF LOCAL AREA NETWORK ARCHITECTURES FOR THE STOCK POINT LOGISTICS INTEGRATED COMMUNICATIONS ENVIRONMENT (SPLICE)

by

Louis S. Hollier, IV
June, 1983

Thesis Advisor: Norman F. Schneidewind

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# Evaluation of Local Area Network Architectures for the Stock Point Logistics Integrated Communications Environment (SPLICE)

by

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Major, United States Marine Corps
B.S., United States Naval Academy

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN COMPUTER SCIENCE

from the

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June 1983

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# ABSTRACT

The Navy Supply Systems Command has developed the Stock Point Integrated Logistics Communications Environment (SPLICE) concept. It will be a foreground and background distributed system built around local area networks. This research describes an evaluation strategy to identify off-the-shelf local area network architectures to support SPLICE. The strategy develops a performance classification system for local area network architectures and identifies evaluation guidelines based on the functional needs of the SPLICE system. Then the evaluation process is implemented to identify example local area network products with architectures that meet SPLICE needs. An example local area network architecture is identified as an architecture that can support computer networking needs in the SPLICE background environment of mainframe computers. A second example local area network architecture is identified with the performance capabilities necessary to support a foreground environment of supply customer work stations.

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# I. INTRODUCTION

## A. DISCLAIMER

The ideas and opinions expressed in this thesis are entirely those of the author and do not necessarily represent the position of, or an endorsement by the Naval Postgraduate School, or the Naval Supply Systems Command and Fleet Material Support Office.

## B. SPLICE OVERVIEW

The Navy supply system, at Stock Points (SP) and Inventory Control Points (ICP), is faced with providing interactive processing and telecommunications capabilities to customers in meeting their growing logistical demands. In order to meet this need for a distributed data processing capability, the Stock Point Logistics Integrated Communications Environment (SPLICE) project concept has been developed. This concept is designed to augment exsisting Navy SP and ICP data processing facilities which support the Uniform Automated Data Processing System for Stock Points (UADPS-SP). SPLICE will provide support for projected increases in workload volumes, interactive processing, and networking requirements for the SP and ICP supply system and its customers.

The SPLICE concept is based on providing distributed data processing facilities to 62 Navy stock point inventory activities using local area networks. The local area networks will be used in a SPLICE configuration at each location, and the networks will support a "foreground" and "background" concept. The local area networking concept will provide a data communications service for both

customers and Stock Point data processing operations. Within each configuration, SPLICE minicomputers will serve as a Front End Processor (FEP) system to off load communications management functions from "background" stock point host mainframe computers. In addition, the SPLICE minicomputers will support an interactive processing service for customer work stations in the "foreground" complex and host mainframe computers in the "background". The SPLICE FEP system will also enable local area network users to communicate with other users at other SPLICE locations via the Defense Data Network (DDN).

The SPLICE project is designing a supply system that is built around local area networks at 62 SPLICE locations. In order to speed implementation, avoid development costs, and establish a uniform system, it is the policy of the SPLICE project to make maximum use of currently available off-the-shelf hardware and software [Ref. 1]. Within the scope of this policy, the SPLICE system must fit within the technology and capabilities of the ADP marketplace [Ref. 2]. To meet the needs of the supply system, commercially available local area network architectures must be identified to support the distributed processing needs of the SPLICE project.

## C. LOCAL AREA NETWORK EVALUATION STRATEGY

This paper presents a strategy for evaluating commercially available local area network architectures for use in distributed computer processing systems. This methodology will be demonstrated by evaluating local area network architectures to identify those that can support the distributed system concept developed for the SPLICE project. The strategy for evaluation of off-the-shelf local area network architectures for SPLICE will consist of a series of three

operations or phases. These phases set the stage for the next three chapters. The phases are briefly outlined below:

> PHASE ONE. This phase will examine commercial local area network architectures and develop a performance classification system for the network architectures. General performance capabilities will be identified for each performance category. In addition, local area network products will be classified based on their architecture.
>
> PHASE TWO. In this phase SPLICE local area network design concepts will be identified. Based on the SPLICE needs a set of performance related evaluation requirements and criteria will be identified to guide the process of evaluating local area network architectures.
>
> PHASE THREE. In this phase the evaluation process will be implemented. Evaluation requirements will be mapped against the performance capabilities of local area network architectual performance classes. This will identify architectual classes that meet requirements. Within those classes, evaluation requirements and criteria will be used to identify example local area networks that meet the distributed design needs of SPLICE.

This evaluation strategy will serve to identify example local area network architectures that meet the needs of the Navy's SPLICE/UADPS-SP system.

# II. COMMERCIAL LOCAL AREA NETWORK ARCHITECTURES

## A. NETWORK ARCHITECTURAL DESIGNS

Local area networks have developed in recent years to meet a wide range of applications in business , industry, and government. The increased demand for networking capabilites and data communications has resulted in a proliferation of companies offering local area network systems. Off-the-shelf local area network architectures implement a variety of technological designs in order to provide a network and communications service fitted to customer needs. The procurement of local area networks to support the SPLICE system requires an evaluation of the performance capabilites of a range of local area network architectures. The evaluation process is faced with gaining a meaningful understanding of the environment in which the evaluation will be made. Understanding the architectual environment will enable the evaluation process to focus on identifying products with architectures that can meet SPLICE needs. To support the evaluation process a means of classifying local area network architectures and products based on performance capabilites is needed.

A local area network architecture is an integration of hardware and software technologies that function to provide a computer network which operates in a limited geographical area. Local area network technologies are based on a combination of new technologies and applications from long-haul network technologies. In attempting to evaluate local area network technologies and architectures a conceptual model or structure is needed in order to begin classifying and understanding the performance capabilites of local area networks.

In 1979, the International Standards Organization (ISO) published the open systems interconnection (OSI) model. This model was intended to provide some degree of compatibility in the development of network architectures. This compatibility was needed to support one of the basic objectives of a network: the objective to allow users to interconnect networks in order to share data processing resources with no concern for hardware and software compatibility and allow applications to be distance independent. The OSI model was intended to become a standard to insure compatibility in a multivendor market. This is a noble goal, but it has not been achieved to date in the free market. However, the framework of the model has been widely adopted by manufacturers and network designers.

The OSI model is important because it divides the communications processes of a network station into seven hierarchical layers of sevices that function to exchange informaton between two network stations. The OSI layers are

| LAYER | NAME |
|---|---|
| 7 | Application |
| 6 | Presentation |
| 5 | Session |
| 4 | Transport |
| 3 | Network |
| 2 | Data Link |
| 1 | Physical |

**Figure 2.1 OSI Model Layers.**

depicted in figure 2.1 . Each layer in the model has a peer-to-peer protocol or service relationship with its counterpart layer for connected network stations. It is these services or protocols that must be compatible for two stations to exchange information on a network.

Local area networks generally span the services of the bottom two OSI model layers, the physical and the data link layers. The physical layer provides the service to connect to, transmit on, and receive signals on the network transmission medium. The data link layer provides the service to gain access to the shared transmission medium, address a set of data to a network station, and then release the transmission medium. Using the bottom OSI layers, the attributes of different local area network architectures can be surveyed with the goal of understanding their performance characteristics. The OSI physical layer is a frame of reference to evaluate the network transmission medium, and the data link layer provides a frame of reference to evaluate the network access methods, and there related network topologies. In addition, the physical and data link layers provide a means to classify local area network products in groupings with similar performance characteristics.

## B. THE PHYSICAL LAYER AND THE TRANSMISSION MEDIUM

Many local area network capabilities are dependent on the characteristics of the transmission medium used. The transmission medium is a physical resource shared in a local area network architecture. One reason to develop local area networks was to eliminate many point-to-point cable links between data processing equipments. Links that have tended to evolve in organizations without a networking plan. The result was often hidden "snake farms" in the cable trays or conduits under the floors, in the ceiling, or in the walls of facilities used by an organization. Local area networks help solve cable installation and maintenance problems by providing means to share a single cable for communications between data processing equipments.

The transmission medium for a local area network is a critical part of the installation. There are four popular transmission mediums used in local area networks. They are shown in figure 2.2 . The medium must be rugged and able to endure handling by construction and maintenance personnel. It will be pulled through conduits and bent around corners and obstacles within, and between buildings. Once in place it must be able to maintain its performance subject to the assault of elements and extremes in temperature. Not only withstanding the abuse of humans and nature, it must also sustain a transmission capacity to meet the data communications needs of an organization.

twisted pair wire or cable
baseband coaxial cable
broadband coaxial cable
fiber-optic cable

**Figure 2.2 Popular Transmission Mediums.**

The performance capability of the transmission medium is reflected in the "transmission service" that the physical layer provides to the local area network architecture. The performance capability of the transmission medium, for the local area network architectures, can be evaluated in three general areas: capacity, connectivity, and reliability. Attributes which generally relate to each performance area for local area network (LAN) architectures are depicted in figure 2.3 . A review of the primary characteristics and attributes that affect the performance of each transmission medium is made in the following sections. The review is done

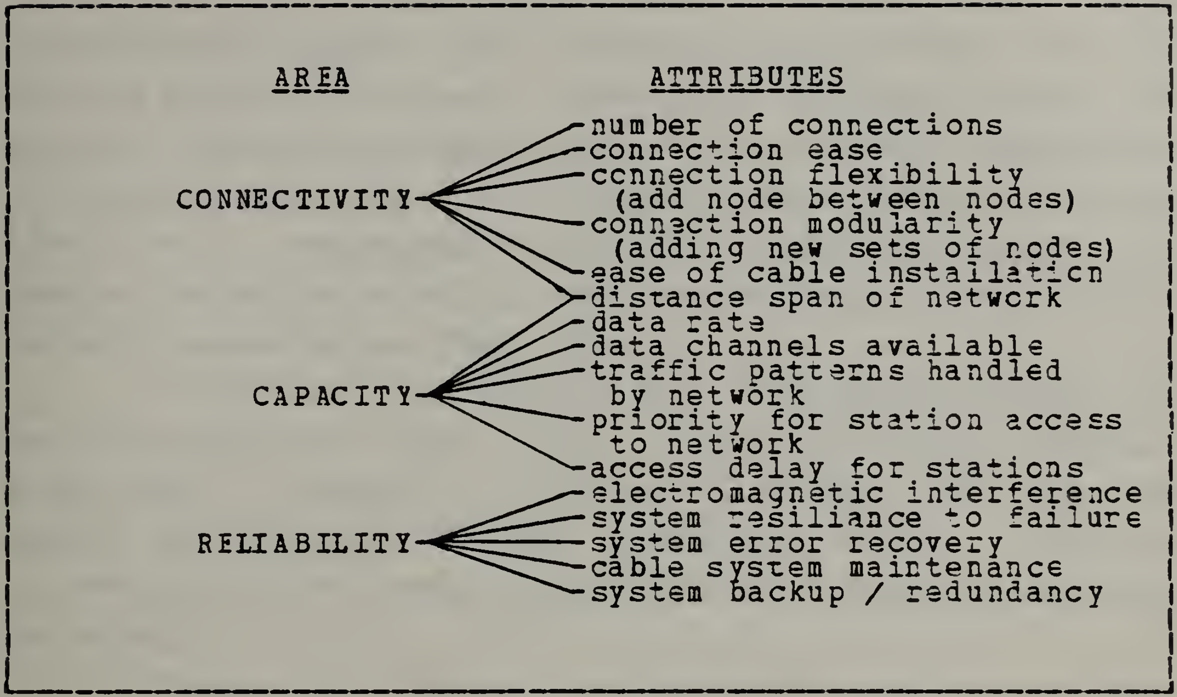
AREA
ATTRIBUTES
CONNECTIVITY
number of connections
connection ease
connection flexibility (add node between nodes)
connection modularity (adding new sets of nodes)
ease of cable installation
distance span of network
CAPACITY
data rate
data channels available
traffic patterns handled by network
priority for station access to network
access delay for stations
RELIABILITY
electromagnetic interference
system resiliance to failure
system error recovery
cable system maintenance
system backup / redundancy

Figure 2.3 LAN Architectural Performance Areas and Attributes.

in order to assess performance capabilities that the local area network architectures will have, based on the transmission medium used in the physical layer.

### 1. Twisted Pair Wire or Cable

Twisted pair wire is a transmission medium used in many local area networks for personal microcomputers in small business organizations. Twisted pair wiring is the same as used for telephones. It is relatively low cost and can be easily and quickly installed. However, it does have performance limitations. The wiring possesses relatively unpredictable electrical impedance characteristics which cause difficulties with impedance matching and reflections. In addition, it tends to both emit and pickup electrical noise. Due to these characteristics data rates and distance spans of the network must be kept low. Typical data rates

range from 240 Kbps (kilobits per second) to 1 Mbps (Megabits per second) over network distance spans of a few hundred feet to 3000 feet. The data rate for twisted pair wire is inversely proportional to the distance spanned by the network [Ref. 3]. In addition, data rates are usually kept low in comparison to other transmission mediums to insure impedance matching and reflections do not affect network transmissions [Ref. 4].

Installation of twisted pair wire often requires the use of conduit and cable trays . This multiplies installation costs; however, it serves to protect the wire from damage and isolates it from electrical noise. Physical connections can be easily made by either tapping or splicing the wire.

Twisted pair wiring has drawbacks due to its relatively low data rate and sensitivity to noise interference. Despite its disadvantages, twisted pair wiring provides a cost effective transmission medium for the less demanding needs of small business networks using personal microcomputers. Networks using twisted pair wiring can be quickly and inexpensively installed to meet their office needs.

### 2. Coaxial Cable

Coaxial cable provides a practical state-of-the-art approach in implementing the physical layer of a local area network. As a result it has become the most popular local area network transmission medium. The technology for coaxial cable has emerged from two areas. The baseband technology was the first to be used in local area networks. It evolved with the computer industry as a means to provide digital signal transmissions between data processing equipment. In recent years it has become the most popular transmission medium for local area networks. On the other hand, the broadband coaxial cable technology developed in the cable

television (CATV) industry. Broadband cable uses radio frequency (RF) transmissions for communications. Recently broadband cables have been used in local area networks. The significantly greater capabilities of broadband have made it a competitive alternative to baseband coaxial cable for use as the physical layer in local area networks. The potential local area network customer's choice between a broadband or baseband local area network must be based on a well defined set of performance requirements to insure the most cost effective choice is made.

### 3. Baseband Coaxial Cable

Baseband is the simplest of two coaxial cable approaches. A baseband local area network provides a single communications channel for digital signals. That channel is shared by all stations attached to the network. Baseband coaxial cable is used by many vendors in their local area networks. Baseband implementations are backed by a proven technology. Baseband provides a high capacity medium that is simple to install and has low hardware costs. However the overall performance of a baseband network depends on the combination of access method, number of attached stations, and distance spanned by the network. The overview of baseband performance chacteristics shall highlight that dependency.

Baseband coaxial cable offers a single channel bandwidth of less than 100 MHz. Typical baseband implementations support data rates in the range of 1 to 10 Mbps over distances of 3000 to 7500 feet. With special techniques a data rate of 50 Mbps over a distance of 3000 feet has been achieved with baseband. In typical networks, depending on cable specifications, increasing the spanning distance by several hundred feet can be achieved with data rate reduction of a few megabits per second. However, as with any

system the trade off may not be so clear cut. Distance on a baseband cable plant can be increased by adding cable segments. Repeaters are required to regenerate signals when the cable length exceeds an allowable maximum, usually 1500 to 3600 feet, or when the transceivers for attached stations exceeds a maximum number, usually 100 to 250.

Baseband coaxial cables are designed for noise immunity and ruggedness. The cables generally have a copper center conductor surrounded by a nonconductive insulator. Around both is a copper mesh encased in a polyvinyl jacket. Diameter of the cable ranges from .3 to 1 inch. The cable design with the wire mesh allows for easy use of vampire or penetrating type taps. However, the mesh design also makes the cable less rigid so conduit must be used to support the cable for installation.

Installation of baseband cable is relatively easy. The cable needs to be routed in a facility near the location where a physical connection is to be made. For a bus or broadcast type configuration of the baseband cable a connection is made by a transceiver. The transceiver connection is made with a pressure type or vampire tap which "cores" the cable. This connection can be made without disrupting the network operation. Controller hardware is attached to the transceiver to implement the data link service when powered. The simplicity of routing the cable directly to the location for a connection may present a problem in providing adequate cable trays or conduit to protect the cable. Transceivers may be placed on the cable in anticipation of future connections. Their placement will have no effect on the cable as long as they are left unpowered by a controller. Placement of transceivers can be arbitrary, subject to a minimum spacing limitation of 5-6 feet between them. Repeaters lend flexibility to cable plant design. Cable segments are typically 1500 to 3600 feet. Repeaters,

which regenerate signals, are used to connect two cables or multiple segments to form star and tree configuations. The use of repeaters then becomes the limiting factor on the distance spanned by the cable plant. Repeaters regenerate all signals on the coaxial cable. That means they amplify both valid signals and noise without any discrimination. If too many repeaters are used the valid signal is lost. Therefore, there is a maximum number of repeaters that can be used between any two stations on the network, usually 2 to 5. This limits the spanning distance of a baseband cable network to a range of approximately 7500 feet.

Baseband cable systems, with cable segments between repeaters, permit easy fault isolation of damaged cable segments. Cables can be separated at repeaters and tested, using manual trouble shooting techniques, to isolate a damaged cable segment for repair or replacement. In addition, connectors can be placed in the cable at predetermined intervals to permit easy replacement of damaged segments without affecting a large number of connections. The connectors can also be used to install temporary bypass segments while repair work is being done. This will permit the network to function less the stations connected to the damaged segment. [Ref. 5]

Redundant cable configurations are use in only a limited number of baseband networks. Use of redundant cables requires the use of special controllers or adapters to provide multiple connections of data processing equipment. The added hardware cost can be offset by an increase in data rates and network reliability. Multiple redundant cables can be simultaneously used to increase data rates, and failure of a single cable will still enable the network to continue operation at a reduced data rate. However, installation of redundant cables will require route planning to insure the physical separation of cables to avoid damage to more than one cable at any single location.

Baseband coaxial cable is a network transmission medium that is simple to install and relatively easy to maintain. It can support high data rates over distances typically required by of local area networks. With the use of digital signaling it provides an effective and reliable data communications medium that is widely used in off-the-shelf local area network architectures.

### 4. Broadband Coaxial Cable

Broadband coaxial cable systems have a high bandwith, 250 to 400 Mhz, and radio frequency (RF) transmissions With these characteristics broadband can offer a higher communications capacity than baseband. Broadband systems offer data capacities from 1 to 25 Mbps. The wide range in data capacities is dependent on the capacity of the RF modems used in the system. The higher the capacity of the RF modem the higher the cost. RF modems accept data signals from devices attached to the network and convert it to RF signals. The RF modem signals are assigned to preassigned RF channels utilizing frequency division multiplexing (FDM) techniques. In order to efficiently share RF channels, the RF modems can also use time division multiplexing (TDM) access methods. RF modems operate from a few bits per second up to 5 Mbps. A typical broadband cable network can use five 5 Mbps channels and still use less than 30 Mhz of bandwidth. This is only a fraction of the available bandwidth in the system. Hence, a majority of the cables capacity is available for video and voice communications services when special voice and video modems are installed. A broadband cable network can simultaneously support low and high speed digital channels, and analog traffic using different RF channels. Broadband cable offers a capacity that meets the data communications needs of most users and still has the capacity to support adding video and voice services.

Broadband can provide a network service over greater distances than baseband. This is due to the performance chacteristics of RF transmissions which minimize phase and amplitude distortion and limits low frequency noise. The broadband network technology utilizes a Central Retransmission Facility (CRF) which receives RF signals from devices on low frequency channels, filters, amplifies, and retransmits the signal on a higher frequency channel to all devices. Broadband cables use passive splitting and branching techniques, unlike the active repeater used in baseband. With passive cable splitters, RF signals can be distributed in local facilities without the use of amplifiers. When distances exceed 2000 feet, amplifiers with filters can be used to extend the network span up to 40 miles.

The use of a broadband coaxial cable plant offers the ability to make connections to many users. Typically, the number of physical connections to a network range from 200 to over 10,000. Off-the-shelf hardware technology develcped in the cable television industry provides versatile combinations of cable splitters, taps, feeder cables, user outlet tap cables, and trunk cables to facilitate broadband cable installation. Broadband trunk cables have solid aluminum shields which make them more rigid than baseband cables. The aluminum shield inhibits use of "vampire" taps but also reduces the need of using conduit to protect cables. In addition, with the use various combinations of cable splitters, feeder cables, and user outlet tap cables, network installers can provide user connections at virtually any work location. Using installation hardware, user connections can be easily made to main trunk cables. This can be done without laying main trunk cables too near user work sites where they are more apt to be damaged. This combination of factors is important to achieving both connectivity and reliability in the system.

A major consideration in the installation of a broadband system is the RF modems needed to make user connections. Many vendors offer RF data modems and costs increase with the capabilities of modems. A typical price range may be $750 for a 9.6 Kbps data rate modem to $6000 for 5Mbps data rate modem. However, a single modem may service a single mainframe or minicomputer, or with a controller, a cluster of terminals.

A broadband network is flexible in supporting user modifications and additions. When work functons change at a user site or are moved between exsisting sites, all that is required is a switching or replacing of the RF modems to meet user needs. Adding new users involves installing appropriate hardware connections, an RF modem, and adding the new station to the network directory. Cable extensions and amplifiers can be used to add new floors or new buildings to a network. This can be done without modification of currently operating network facilites.

A broadband network requires an extensive hardware investment to establish the intial system. Communications planners must analyze data rates and channel requirements needed by the user in order to identify a cost effective mix of RF modems to be used in the system. In addition, the systems layout in terms of RF power must insure that the central retransmission facility is optimally located. Once installed, the network must be tuned for impedance and signal levels.

Broadband systems offer a number of features which enhance reliability and provide for system backup. The hardware used for installing cable plants is backed by the proven and time tested technology of the CATV industry. Maintenance of a broadband system can be automatically controlled by a monitor system. A monitor system is usually located with the central retransmission facility. The

monitor system can monitor the network facility in real time, provide detailed fault analysis, recommend repair procedures, and maintain a network management and informational database. Redundancy can be easily implemented when it is necessary to provide backup systems for the network. The low expense of central retransmission facility equipment permits redundant installation. In addition, the simplicity of central retransmission facility equipment promotes high reliability and easy repair. Redundant installation of amplifiers is done by using hot standby amplifiers or connecting two amplifiers in parallel. Networks can be installed with redundant cables. When redundant cables are installed, user connections are made to the cables using cable splitters so communications can be implemented on either cable. Using the above techniques, redundancy can be easily implemented throughout a broadband cable system to insure reliability.

In addition to flexibility and connectivity of the physical installation, a broadband system can be used to achieve multiple logical configuations using channel and frequency assignment schemes. This enables a single network to be used as multiple networks on a one cable system. This design technique can be used to connect groups of devices that are compatible with each other on one channel, but are not compatible with other devices in the organization. This can serve to reduce the need for specific network interfaces for equipments that share a common protocol [Ref. 6]. RF channels within the network can be dedicated in support of specific functions, for priority users, and security applications. In addition, control and data channel combinations can be implemented on the network to support communications management functions.

Broadband coaxial cable networks offer the capability to handle combined data, voice, and video communications for thousands of users over a wide geographical area. Fiber optic sublinks, which are used to provide isolation or security for network nodes, can be used with broadband networks [Ref. 7]. Refinements and new innovations in broadband cable, hardware, and RF modems can be expected for future broadband systems.

### 5. Fiber-Optic Cable

Fiber-optic cable technology, with the use of light wave transmissions, offers many potential advantages over conventional metallic transmission mediums. However, it is only beginning to make its debut from the experimental environment. As a result, off-the-shelf commercial applications are limited. Its use in local area networks has been generally limited to point-to-point communications links. However, the medium does offer characteristics which make it useful in specific applications.

Fiber-optic cables offer an extremely high bandwidth, 1 to 2 GHz (billion cycles per second). The major drawback to using fiber-optic cables in local area networks is the lack of suitable cable splitters to facilitate branching and cost effective taps to add stations.

The fiber-optic medium does offer potential advantages that should motivate its technological development in the next decade. Fiber-optic cable has no electrical current to produce sparks which makes it suitable for use in explosive environments. It is immune to electomagnetic and radio frequency interference, unlike metallic cables, so transmission are of high integrity. It offers a relatively secure medium that cannot be "bugged" without actually tapping the cable, which is a difficult and detectable process. Fiber-optic cables are light weight, compact, and rugged.

They can be easily installed and have the capacity to replace coaxial cables 20 times their size and weight. The potential for easy and low cost installation make it an attractive alternative for use in local area networks located in crowded business areas.

Improvements in the installation technology for fiber-optic cables can be expected in the next few years. Technology advances should include the development of improved cables, cable splitrers, and taps. These technological advances are needed to make it a practical transmission medium for local area networks.

A comprehensive survey of fiber optics as applied to local area networks is beyond the scope of this thesis.

## C. THE DATA LINK LAYER

The data link layer is the second layer of the OSI model. It provides the service necessary to communicate on the shared transmission medium of a local area network. The layer provides for the exchange of data between any two stations on a logical network link. The factors needed to implement this service are a network access method and its related shared cable topology to establish a logical link between two stations, and a link control protocol to manage the exchange of data between two stations.

The network access method and its related cable topology are the key factors in establishing a logical communications link between two stations on the network. The topology of the network insures that logical communications link does in fact have a path on the transmission medium between two stations. The access method provides a mechanism by which a station acquires and subsequently releases the shared transmission medium.

The actual data transfer on a logical link is accomplished by a link control protocol. Once the transmission medium has been accessed, the link control protocol functions to frame the data in a packet, and controls the exchange of both control information and data on the communications link. Packet switching techniques such as X.25 and bit oriented protocols such as High-level Data Link Control (HDLC) used in long haul network architectures in the past decade have been a basis for designing link control protocols. The protocols used provide a means to identify, or frame, the data and control information sent on a local area network. Normally, sender and receiver addresses are identified in the frame formats. The framing mechanisms are used to indicate the begining and the end of each frame. In addition, error detection codes and supervisory data are used to reveal errors and delimit or synchronize interpetation of the data in a frame.

In order to evaluate the performance chacteristics of commercial local area network architectures from the data link perspective, the classification of architectures based on access method and topology is useful. In the realm of local area networks, many combinations of access methods and topologies have been used in experimental, in custom built, and in off-the-shelf networks. However, to focus on off-the-shelf commercial local area network architectures, the access method and topology categories are narrowed down to five combinations depicted in table I .

The performance capability of each access method/ topology class can be evaluated in three general areas: capacity, connectivity, and reliability. Local area network architectural attributes which generally relate to the general performance areas are depicted in figure 2.3 .

## TABLE I

## Access Method and Topology Categories

| ACCESS METHOD | TOPOLOGY |
|---|---|
| CSMA/CD | Bus |
| Token Passing | Bus |
| Token Passing | Ring |
| Slotted | Ring |
| Central Controller | Star |

### 1. Central Controller - Star Topology

Star networks have their acess control based at a central or controlling master station. In commercially available networks, twisted pair wire and coaxial is used in the physical layer. The transmission medium is used to connect each station to the master station in a star configuration. In the star network, the master station functions as a switching unit which establishes point-to-point connections between communicating stations. This type of network implementation is popular for use with microcomputer networks used in offices of small businesses and organizations.

Central control star networks have data rates that range between 400 Kbps and 800 Kbps over distances of up to 1000 feet [Ref. 8]. They have the advantage of a simple access method which involves polling schemes used by the central station. The polling schemes provide virtually contention free service with low traffic delays. The polling access methods can easily handle bursty, regular, or real time communications traffic. In terms of reliability, single station failures or damage to a transmission line will effect only a single station in the network. However, a major disadvantage of the system is that a failure of the

central station will terminate network service if an on-line central station is not used for backup. Another disadvantage is that there is a limit to the number of stations that can be directly connected to the cental station.

### 2. The Bus Topology

The bus topology is used in the implementations of both the Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Bus and the Token Bus access methods. The bus topology has inherent performance characteristics common to both implementations. In a bus topology transmitted messages are broadcast by the originating station over the entire network. Stations sharing the network must check the message to determine if they are the destination station of the message. Broadcasting is simple because routing or forwarding of the message is not needed. The absense of routing or the forwarding of messages supports reliability since network resists single point failure of a station. A bus topology supports a high degree of connectivity with any transmission medium. It has the flexibility to easily add new stations between exsisting stations on the bus. In addition, the bus can easily support modular extensions which involve adding cable extensions with stations in new sites of a facility. Another unique advantage of the bus is that it offers the capacity to support access methods designed for a ring topology. The bus can be used to form a "logical" ring in order to implement access methods designed for ring topologies; the reverse is not possible for the ring.

### 3. CSMA/CD Bus

The Carrier Sense Multiple Access with Collision Detection (CSMA/CD) is an access method used to share the transmission medium in networks with a bus topology. This

is a random access method for accessing the bus which is relatively simple to implement. As a result, CSMA/CD is used in many commercial local area networks. To transmit a message, each node or station on the network listens for broadcasts on the cable and senses when it is not in use. If the cable is idle, the node immediately assumes control of the cable and transmits a message frame. To avoid simultaneous transmissions, a station will normally monitor the cable during transmission to detect a collision with another node's transmission. In the event of a collision both nodes will cease transmission and wait a random time before attempting transmission again.

The CSMA/CD access method is simple to implement using most transmission mediums. CSMA/CD's performance in terms of capacity for typical commercial networks is reflected in the table II . CSMA/CD has the advantage of being able to meet high demands of bursty users and still maintain high utilization of the network. Studies indicate that when network stations offer a traffic load above 100% of the network data rate, utilization remains above 95% [Ref. 5]. An issue often raised over CSMA/CD concerns the nondeterministic delay that stations face in real time

TABLE II
Typical CSMA Capacity Performance

| MEDIUM | DATA RATE | DISTANCE |
|---|---|---|
| Twisted pair wire | 1 Mbps | 1000 feet |
| Baseband coax | 10 Mbps | 7500 feet |
| Broadband coax | 5 Mbps/channel | 50000 feet |

[Ref. 18]

applications. This is often sighted as a factor to favor polling or token access methods. However, when the probability of recovering a lost or damaged token is considered, these access schemes also have a nondeterministic attribute when supporting real time applications [Ref. 9]. A traffic capacity disadvantage of CSMA/CD is that there is no priority mechanism, all stations have equal access to the network. This might be considered a critical disadvantage when real time process control communication is needed by a user.

The CSMA/CD method has the advantage of supporting flexibility and modularity in adding network stations. The control for accessing the network given to each station by the CSMA/CD will result in significant performance degradation when a large number of stations are connected. The number of stations that can be connected is also limited by the number of physical connections that can be made to the transmission medium or the addressing format used in the link control protocol.

In terms of reliability, the advantage of distributed access control for CSMA/CD networks is that station failures do not affect the system. Hence, a complete system recovery is not necessary for a station failure. However, it is desirable to initiate recovery action for the failed station ( i.e., to diagnose and possibly repair the failed station or to transfer the failed station's workload to an operational station). A reliability disadvantage for CSMA/CD networks is that collision detection depends on good transmission characteristics of the transmission medium. This is of concern when using twisted pair wire or baseband coaxial cable. During a transmission, noise and reflections from a damaged cable or faulty connection may be recognized as a collision and the transmission will be aborted. This will continue until the fault is repaired. However,

broadband coaxial cable which transmits and listens on separate channels is less suseptable to the problem. Broadband networks use a central retransmission facility to retransmit a message for broadcast on a higher freqency than originally transmitted on. Broadband collision detections are usually made by a bit by bit comparison of the retransmitted messages on the higher frequency channel to the message originally sent.

CSMA/CD is a simple access method that can be effectively used with a variety of transmission mediums. It is the most popular access method used by commercial local area network vendors.

### 4. Token Passing Bus

The token passing bus is a variation of the token passing ring access method. However, a bus topology is used, and the stations or nodes are considered to be in a "logical ring". This access method is a complex implementation; however, it does offer unique performance characteristics. This method is a polling scheme in which a control token is passed from node to node in a "logical ring" sequence. Only a station that has the token has the right to broadcast a message over the bus while others listen. At the end of the transmission, or if the node has no message to send, the token is passed to the next node in the "logical ring" sequence. Normally, a node can retain the token and transmit messages for only a specified period of time.

The token passing bus offers a unique set of performance characteristics. In terms of capacity, typical networks have data rates of 2.5 Mbps to 1 Mbps over distances of 5000 and 30,000 feet, respectively. These capacity characterisics represent a trade off between data rate and distance in the networks. A disadvantage is that for bursty traffic, the network bandwidth is not available

on demand. The token passing scheme has an overhead in available network bandwidth. A traffic capacity advantage is that the polling scheme has a deterministic delay for a node's access to the network. However, this should be considered in respect to the probability of recovering a lost token in real time.

In terms of reliability, the token passing on a bus does not depend on a physical ring, only a logical ring. Conventional physical ring networks are susceptible to failure when a single node fails, but the logical ring of the bus is not as susceptible to failure. However, the potential of losing a token to noise on the bus, or when a node fails, does pose an important reliability consideration. Token recovery procedures must be effective in making recovery on a real time basis.

Connectivity performance of the token passing bus retains the desireable features of a bus topology for adding new nodes. However, a set of complex algorithms are needed to start up the network system, and to efficiently add and delete nodes from the token passing scheme [Ref. 10].

Overall, the token passing with a bus topology is a complex local area network implementation. However, it does gain real time processing advantages for the bus topology while avoiding the reliability and connectivity disadvantages of token passing on a physical ring.

### 5. The Ring Topology

The token ring and the slotted ring access methods both use a ring topology. The ring topology has performance characteristics inherent to both access method implementations. In the ring, message traffic flows in one direction around the ring. A message transmitted by a node in the ring is received and forwarded around the ring by the other nodes until the message is received by the originating node. Nodes

form an active string of repeaters for the transmission of messages on the ring. This design has both performance advantages and disadvantages. In terms of capacity, the use of retransmission at each node can provide a high network data rate if short distances are maintained between nodes. Using nodes as an active repeater string also allows the network to span long distances. This use of point-to-point transmissions enables the network to span long distances while using twisted pair wire or coaxial cable. The ring topology performance in terms of connectivity has disadvantages in some implementations. The flexibitiy to add new stations between stations is minimal. In order to add a station the cable must be cut to install a repeater for the connection. This process disrupts the entire network. Modular expansions of the network to add new stations in a outlying locations also requires cutting the cable and disrupting the network. In addition, running a cable in the hidden locations of conduit, cable trays, ceilings, floors, and walls, while still maintaining the "ring" configuration, is a challenging problem.

In terms of reliability, the ring topology has additional performance disadvantages. In some ring networks, operation of the network depends on the reliability of a repeater string. A single point repeater failure can break the ring and down the network. Techniques to bypass the failed nodes are available. However, if distances between the nodes are long, the increase in transmission distance by bypassing a failed node can create problems if there is no signal regeneration. Bypassing one node will double transmission distance, and failure of adjacent nodes, could triple the transmission distance. This effect limits the distance that can be between nodes in a network. [Ref. 3]

The ring topology has capacity advantages in data rates and distance span of the network. However, this is achieved with a trade off that limits connectivity and reliability of the network implementation.

### 6. Token Passing Ring

The token passing ring access method is implemented with stations or nodes in sequence in a ring configuration. In this access method a control token, message frame, is circulated around the ring. If a station has a transmission to make it removes the token, sends a data frame, and then puts the token back into circulation. The sequence in which the token is passed is not necessarily dependent on the physical sequence of the stations. Each station must check the desination address of the token since only the destination station may remove the token to transmit. Data transmissions on the ring are regenerated at each node in the physical ring sequence. Destination nodes may copy data from the data frame, but only the originating node can remove the data frame and return the token. Only one message can be on the ring at one time. Since a single token controls all messages, collisions are not possible and collision recovery procedures are not needed. In addition, the use of a token provides for decentralized access control.

Token passing rings have capacity advantages. With point-to-point transmissions between nodes, data rates are typically 10 Mbps with distance limits between nodes of 750 feet using coaxial cable. Also, wide network spanning distances are possible if repeaters are used between stations. However, the number of repeaters that can be placed between active stations has a limit because the repeaters amplify both valid signals and noise without discrimination [Ref. 11]. The point-to-point transmissions

allow for easy adaptability of various transmission mediums. However, the use of baseband coaxial cable is the most common. The access method can be used to support a priority scheme for access of stations to the network. The polling technique used with the token gives stations deterministic access delay times. However, the probability of recovering from a lost or damaged token can give the access delay time a nondeterministic attribute [Ref. 9]. In addition with token passing, high user traffic rates are serviced with no degradation of network services as a result of collisions.

In contrast to the capacity advantages, token passing rings have inherent disadvantages in connectivity and reliability due to their physical ring topology. The key disadvantage in reliability, is the ring topology's dependence on an active repeater string, in some implementations. In addition, the possibility of losing a token on faulty transmissions requires standby procedures to recover the token. Also in some implementations, the flexibility in adding stations between nodes, and adding groups of stations on modular extensions to the network, is limited by the ring topology.

### 7. The Slotted Ring

The slotted ring access method uses a physical ring topology. Only one commercially available network, POLYNET by Logical Incorporated, was covered. In this approach, the network ring is divided into slots using a circulating pattern of bits. Each slot carries a header which identifies it as an empty or full message slot. A typical implementation provides 16 slots. To transmit, a node seizes an empty slot by marking it full, and inserts an information packet of a fixed size. Each network node receives all slots as they circulate. Each slot is examined by a network node to determine if it is the destination node. If a node is the

destination node of the packet, it copies the data and marks the the slot free, otherwise, it retransmits the full slot. This approach requires an administration node to intiate and maintain the slot bit pattern.

This access method can support a data rate of 10 Mbps using twisted pair wire or coaxial cable. The point-to-point transmissions around the ring facilitate the high data rate. This method has the capacity advantage of being able to support concurrent message traffic for stations on the ring. This feature allows it to easily adapt to a wide range of data rates of attached equipments [Ref. 13]. The number and maximum size limit of the frames, limits the ability to effectively use the available network bandwidth.

In terms of connectivity, the slotted ring method inherits the disadvantages of the ring topology. Stations cannot be added without disrupting the network. Reliability of the slotted ring also has the disadvantage of depending on an active string of node repeaters for network operation. Another reliability disadvantage is that the use of a control node responsible for maintaining the slot pattern centalizes network control. A control node failure will result in network failure.

## D. CLASSIFICATION OF LOCAL AREA NETWORK ARCHITECTURES

In order to evaluate performance capabilities of local area network products, they can be classified based on their architecture. Local area network products can be classified based on the following two areas: the physical layer transmission medium and the data link layer access method with related topology.

Currently available, off-the-shelf, local area networks are classified in three figures. Figure 2.4 classifies local area networks with a central controller access method

<table>
<tr><th colspan="2">June<br>1983</th><th>DATA LINK LAYER<br>Star Topology<br>Access Method: CENTRAL CONTROLLER</th></tr>
<tr><td rowspan="3">PHYSICAL LAYER</td><td>TWISTED PAIR WIRE</td><td>*HINET|500K|1000|32<br>Digital Microsystems/2000<br>*STAR|800K|---|16<br>Televideo / 1600</td></tr>
<tr><td>BASEBAND COAXIAL CABLE</td><td></td></tr>
<tr><td>CABLE COAXIAL BROADBAND</td><td></td></tr>
<tr><td></td><td>FIBER-OPTIC CABLE</td><td></td></tr>
</table>

LEGEND:

Figures 2.4, 2.5 and 2.6 with entries for off-the-shelf Local Area Network (LAN) Architectures.
Entry format:
* LAN name| ① | ② | ③
manufacturer / ④

① : Data rate (bps)

② : Distance span of network in feet or miles (mi), "node" indicates node to node distance for ring networks.

③ : maximum physcial connections

④ : networks installed by manufacturer

"---" data not available

Figure 2.4 Classification of Central Controller Star Networks

|  | June 1983 | DATA LINK LAYER<br>Bus Topology |  |
|---|---|---|---|
|  | Access Method: | CSMA/CD BUS | TOKEN BUS |
| PHYSICAL LAYER | TWISTED PAIR WIRE | *OMNINET\|1M\|4000\|64<br>Corvus Systems Inc./1000<br>*CLUSTERONE\|240K\|3000\|65<br>Nestar Systems Inc./600<br>*MARSNET\|800K\|3000\|256<br>SC Systems Inc. /---<br>*UBITS\|50M\|1000\|16000+<br>AMECON DIV of Litton/--- |  |
|  | BASEBAND COAXIAL CABLE | *DECdataway\|10M\|15000\|31<br>Digital Equip. Corp./---<br>*HYPERBUS\|10M\|2400\|128 #1<br>*HYPERCHANNEL\|50M\|3000\|256<br>Network Systems Corp./900<br>*Z-NET\|800K\|7000\|255<br>Zilog Inc. /---<br>*NET/ONE\|10M\|4000\|300<br>Ungermann-Bass Inc./125<br>*ETHERNET\|10M\|7500\|1024<br>Xerox Corp. /200 | *XODIAC\|2M\|5000\|32<br>Data General Corp./---<br>*ARC\|2.5M\|4mi\|255<br>Datapoint Corp. /4830<br>*MICROLINK\|1M\|6mi\|255<br>Standard Engr. Corp./---<br>*MODWAY\|1.544M\|3mi\|256<br>Gould Inc. / 5 |
|  | BROADBAND COAXIAL CABLE | *VIDEODATA\|100K\|40mi\|248<br>Interactive Sys/3M /250<br>*INFOBUS\|1M\|75mi\|256<br>M/A-COM DCC Inc. /---<br>*LOCALNET\|10M\|20mi\|16000+<br>Sytek Inc. /200<br>*WANGNET\|12M\|2mi\|512+<br>Wang Laboratories Inc./---<br>*NET/ONE\|20M\|10mi\|300+<br>Ungermann-Bass Inc./above |  |
|  | FIBER-OPTIC CABLE | *NET/ONE\|---\|---\|---<br>Ungermann-Bass Inc./above | (note #1 Hyperbus is CSMA/CA) |

Figure 2.5 Classification of CSMA/CD and Token Bus Networks

and a star topology. Figure 2.5 classifies local area networks with CSMA/CD and token access methods that use a bus topology. Figure 2.6 classifies local area networks with token ring and slotted ring access methods that use a ring topology. When local area networks are classified in this manner, performance capabilities can be attributed to each architectural class of off-the-shelf local area networks. An architectural class is identified by both transmission medium, and access method/topology.

This performance classification scheme for local area network products will assist the SPLICE local area network evaluation process. User needs will identify the performance capabilities needed in the SPLICE local area networks. Based on SPLICE needs, the architectual class, or classes, can be identified which have the potential performance capablities to meet those needs. The evaluation process can then focus on example vendor products in the class, or classes, identified.

## E. STATUS OF LOCAL AREA NETWORK STANDARDS

In the face of the growth of local area networks, users have become concerned with their capability to interconnect a variety of data processing equipment with a network, and to interconnect networks. This has generated a need for local area network standards. As a result, local area networks have become a concern of both international and national standards orgnizations in recent years. The major effort has been in the Institute of Electrical and Electronic Engineers (IEEE) Project 802 Committee. The standards effort of Project 802 has been to ensure compatibility between equipment made by different manufacturers, such that data communications can take place with a minimum of effort on the part of builders or users of networks.

| June 1983 | D A T A L I N K L A Y E R |  |
|---|---|---|
|  | Ring Topology |  |
| Access Method: | TOKEN RING | SLOTTED RING |
| TWISTED PAIR WIRE | *PRCTNET\|10M\|600node\|255<br>Protecn Associates /below |  |
| BASEBAND COAXIAL CABLE | *DOMAIN\|12M\|1000node\|100+<br>Apcllo Computer Inc./---<br>*RINGNET\|10M\|750node\|255<br>Prime Computer Inc./---<br>*Stratalink\|2.8M\|1500node\|32<br>Stratus Computer Inc./---<br>*PRONET\|10M\|---\|256<br>Proteon Associates Inc./50 | *POLYNET\|10M\|---\|254<br>Logica Inc. / --- |
| PHYSICAL LAYER<br>CABLE COAXIAL BROADBAND |  |  |
| FIBER-OPTIC CABLE | *PRCNET\|10M\|3000node\|255<br>Proteon Associates /above |  |

Figure 2.6 Classification of Token Ring and Slotted Ring Networks

Since 1981, the Project 802 Committee has had limited success in gaining support for any one approach. However, the standards being considered are compatible with the ISO's Open Systems Interconnecton (OSI) model. Consideration has revolved around CSMA/CD Bus Baseband, CSMA/CD Bus Broadband, Token Passing Bus, and Token Passing Ring. Of primary consideration has been the specifications for a CSMA/CD Bus Baseband specification, using Ethernet as a model. Ethernet was made a defacto standard for baseband local area networks in September 1980, when Digital Equipment Corporation (DEC), Intel Corporation, and Xerox jointly published the specifications. In the fall of 1982, an Ethernet-like specification was recommended by Project 802 to the IEEE. This happened only after it had been adopted by the European Computer Manufacturers Association, and had received the endorsement of 20 network vendors. Final approval of the IEEE Ethernet-like standard is anticipated in 1983.

In addition, for broadband local area networks, the IEEE Project 802 Committee has endorsed a single cable, mid-split frequency allocation standard, TR 40.1. This standard was originally developed and proposed by the Electronics Industries Association (EIA). [Ref. 12]

# III. SPLICE EVALUATION REQUIREMENTS AND CRITERIA

## A. SPLICE EVALUATION PROCESS

The evaluation process for SPLICE local area networks begins with understanding the SPLICE system environment. This understanding will help in developing a strategy to focus on the performance capabilities of the local area network architecture that are needed to support a meaningful evaluation process.

The next step in the evaluation process involves identifying local area network performance capabilities needed for SPLICE. This involves development of evaluation requirements and criteria. Evaluation requirements are those functional performance capabilities which are essential in meeting SPLICE design needs. The evaluation requirements developed are kept to a minimum in order to avoid unnecessary restrictions which would unfairly narrow the evaluation process. However, they must include the minimum set of requirements that, if not met, would make a local area network architecture unsatisfactory in meeting the design goals of the system. Evaluation requirements will be guides in identifying example architectures that meet SPLICE design needs. In order to identify example local area network products, with architectures that meet the requirements, a set of evaluation criteria is also developed. The evaluation criteria serves as a guide to assess the performance capabilities and desirable features of example network products. This assessment will identify local area network architectures that can meet the needs of the Navy SPLICE project.

Functional design needs and specifications for the SPLICE local area networks are found in the Function Description [Ref. 1] and the Solicitation Document [Ref. 14] for the SPLICE project. In addition, a functional design of a local area network for SPLICE has been recommended as a result of research done at the Naval Postgraduate School and supported by the Fleet Material Support Office [Ref. 15]. These documents provide a basis for identifying both the evaluation requirements and evaluation criteria needed for the evaluation process.

## B. SPLICE LOCAL AREA NETWORK DESIGN ENVIRONMENT

The SPLICE system has a need for three data communications networks: one long haul network, and two local area networks. The long haul network, the SPLICE network, will provide data communications between 62 SPLICE locations in CONUS and the Pacific. This network will use the planned Defense Data Network (DDN) to communicate between SPLICE locations. In addition, there will be two local area networks for each SPLICE configuration. There may be one or more SPLICE configurations at each SPLICE location. Within each SPLICE configuration, a local area network is needed to support data communications for a "Background" system, and a second local area network is needed to support data communications in a "Foreground" system. Both local area networks will interface to a "Front End" system, this is a communications management system to support inter-site and intra-site communications. Understanding the SPLICE local area network environment involves understanding the SPLICE configuration of three interrelated systems. A description of each system is provided to provide a basis for defining evaluation requirements and criteria.

### 1. The "Background" System

Within the "Background" system there is a need for a local area network to provide a high speed data channel between host mainframe computers and their peripherial equipment. This high speed data channel can be referred to as the Background Local Computer Network (BLCN). The design concept for the BLCN is to support data communications for host mainframe computer systems. The hosts include Burroughs Medium Computer Systems and other mainframe computer systems that will be dedicated to batch processing and large data base management. Applications that include large file processing and report generation functions will need a very high speed communications service between the hosts and peripheral equipment. In addition, the BLCN will provide the capability to off load data communications management and interactive processing management tasks to the "Front End" system. This facilitates off loading a work load that is beginning to force host computer systems into saturation. The off loading is intended to extend the useful life of the background computer systems into the 1990's. This will allow present applications of the "Background" system to expand without early saturation. At the same time, new applications can be targeted for the "Foreground" system.

The "Background" system will conceptually become a locally expanded, or dispersed, data center operation tied together with the BLCN. This mainframe environment needs relatively little flexibility to reconfigure for new applications. However, the BLCN needs to provide very high capacity and highly reliable data communications service to support present applications as they expand. No single point or data link failure should interrupt the BLCN's communications service. The BLCN evaluation process must focus on performance in terms of capacity and reliability in order to support this mainframe oriented environment.

### 2. The "Front End" System

The "Front End" system is a Front End Processor (FEP) system. This FEP system will interface to both the "foreground" and "background" systems. The FEP will be a minicomputer system designed to off load communications management, and terminal management tasks, from the "background" system. The FEP system will manage both intra and inter site communications for the SPLICE configuration. It will be a three (3) way communications gateway between the "background" system, the "foreground" system, and the SPLICE network. An important concept in the development of the FEP system is the virtual local area network design approach proposed in developing the software modules for communications and terminal management. This design approach supports two functional features important for consideration in the SPLICE local area network evaluation process:

> * The local area networks should support both a datagram and virtual circuit style communications service for intra network communications, and interfaces to the Internet Protocol for inter network communications.
>
> * The local area networks should have a decentralized access control system for sharing the communications medium. This is to support a logical design which has a "virtual" control bus for control messages and a "virtual" data bus for application and data messages. [Ref. 15]

The datagram style message service is typicall used in almost all off-the-shelf local area network architectures using bus or ring topologies.

### 3. The "Foreground" System

The SPLICE "foreground" system is a minicomputer work station complex that is interconnected by a second local area network. The Solicitation Document refers to this as the interprocessing subsystems network. This system of user CRT terminals, or work stations, will support a distribution of data processing functions to the customer work sites. The work stations will become the primary tool for supply customers to conduct business. The work stations will enable customers to share and access information across the local area network and the entire SPLICE system. Customer CRT work stations will support data entry, search, and retrival. Along with the work stations, there will be printers and scanning equipment to produce hard copy reports and facilitate rapid data entry. The work station complex will support a real time, on-line, transaction oriented environment. The local area network will provide the communications substrate to support this distribution of processing power to customers. The strategy in evaluation of the Foreground Local Area Network (FLAN) should focus on providing a flexible customer oriented service. This flexibility translates into providing the capacity and connectivity to support the changing and growing needs of Stock Point customers. In addition, the communications service must be reliable in its support of supply business activities. No single point failure or data link failure should interrupt the FLAN service. The evaluation strategy for the FLAN should be oriented towards adaptability in capacity, and connectivity, in order to meet changing business needs of the customer.

## C. EVALUATION PROCESS FIRST STEP REVIEW

The first step of the evaluation process focused on the SPLICE local area network environment. This identified a strategy to guide the development of requirements and criteria to evaluate local area network architectures. Studying the networking environment reveals a need for two strategies in the evaluation process. The BLCN strategy should focus on a very high capacity and high reliability in the communications service for a mainframe environment. The FLAN strategy should focus on adaptability in the capacity and connectivity of a reliable communications service in meeting customer business needs.

## D. BLCN EVALUATION REQUIREMENTS AND CRITERIA

The evaluation strategy for the BLCN should focus on sustaining a very high capacity and a high reliability data communications service. This service will be the communications substrate for a host mainframe computer environment.

It is the policy of the SPLICE project to make maximum use of off-the-shelf hardware and software. This use of standard vendor products will shorten the time frame in implementing SPLICE. This establishes the first requirement:

> B-R1: The BLCN architecture must be an off-the-shelf system.

The functional design of SPLICE local area networks is based on a virtual local area network [Ref. 15]. This design generates the next requirement:

> B-R2: The BLCN shall support both a datagram and virtual circuit communications services, with decentralized control, that gives each attached host uniform functionality.

### 1. BLCN Capacity Needs

The SPLICE Solicitation Document for the BLCN specifies a data rate of not less than 25 Mbps with an aggregate data rate of 50 Mbps up to a distance of 1000 feet. In addition, a data rate of not less than 1 Mbps with a sustained aggregate data rate of 2 Mbps up to a distance of 5000 feet. The use of two data rates is based on using redundant simultaneously operating data links. This is to enhance the reliability of the system. Considering the networking environment of the SPLICE configuration, the foreground local area network (FLAN) should have the capacity to absorb or off load the 1-2 Mbps data rate over the 1000 to 5000 foot distance. In addition, the background data processing equipment could be reconfigured to place it all within a 1000 foot diameter. This would allow the BLCN to sustain the 25-50 Mbps data rate throughout the network. This generates a requirement and an evaluation criteria:

> B-R3: The BLCN independent of the data rate of attached equipment shall sustain on an as need basis a transmission data rate between attached equipment of not less than 25 Mbps with an aggregate data rate of 50 Mbps at distances up to and including 1000 feet.
>
> B-C1: The capability to maintain a data rate capacity of 25-50 Mbps over distances in excess of 1000 feet is desirable.

### 2. BLCN Connectivity Needs

The BLCN is designed to provide a communications service for host data processing equipment at 62 Navy supply locations. The solicitation document specifies a need to attach a maximum of 32 equipments in a radius of 2500 feet.

This specification must change in order to be compatible with capacity requirements. This generates a new requirement and evaluation criteria:

> B-R4: The BLCN shall be able to connect a minimum of 32 equipments in a radius of 500 feet.
>
> B-C2: The capability to connect 32 equipments in a radius in excess of 500 feet is desirable.

### 3. BLCN Reliability Needs

Splice local area networks are to be configured for a fault tolerant operation. In this light, no single point failure will cause the unavailability of the data processing complex to supply customers. Stock Point and Inventory Control Point operations depend on the availability of computer support to conduct business. The loss of that support will mean lost people time, which is unacceptable [Ref. 1]. The need for reliability generates the following requirements:

> B-R5: There must be more than one communications path, data link, between each pair of equipment interfaces on the BLCN.
>
> B-R6: The operational status of the network will not depend upon the operational status of any attached equipment. The BLCN will operate as an independent, stand alone facility.

Redundant data links are intended to support a fault tolerant operation. In addition, redundant cable configurations will support on line maintenance and reconfigurations for hardware repairs while the system continues processing.

### 4. Additional BLCN Needs

In order to further evaluate local area network products that meet BLCN evaluation requirements, additional evaluation criteria are needed to identify example networks that have a potential for meeting SPLICE design needs. This will aid in evaluating and identifying example off-the-shelf products with architectures that can meaningfully support the SPLICE system over its 11 year life cycle. The additional evaluation criteria are:

> B-C3: It is desired to provide off-the-shelf interface hardware for background data processing equipment. This equipment includes the following computers:
>
> Burroughs Medium System
>
> Perkin-Elmer 3200 series
>
> Interdata 32 bit series
>
> IBM 360/370
>
> Univac 1100 and 490 series
>
> Tandem
>
> B-C4: Compatibility with network standards such as those supported by the IEEE Project 802 is desirable.

## E. FLAN EVALUATION REQUIREMENTS AND CRITERIA

The evaluation strategy for the Foregroud Local Area Network (FLAN) should focus on providing a communications service adaptable to customer needs now, and in the future. In this respect, the FLAN should provide an adaptable performance in terms of capacity and connectivity to meet

changing and growing user needs. In addition, it must be a reliable communications service for supporting customer business activities.

It is the SPLICE project policy to achieve rapid implementation by making maximum use of off-the-shelf products. This establishes the first requirement:

> F-R1: The FLAN architecture must be an off-the-shelf system.

The functional design of the SPLICE local area network is based on a virtual local area network. This design generates the next requirement:

> F-R2: The FLAN shall support both a datagram and virtual circuit communications services, with decentralized control, that gives each attached host uniform functionality.

### 1. FLAN Capacity Needs

The FLAN will support a high speed data communications service between attached work stations. It must sustain a high data rate to provide an efficient interface with the BLCN during data exchanges. This will also serve to reduce buffering requirements in the system. The FLAN, if necessary, must be capable of supporting "background" data processing equipment that cannot be directly attached to the BLCN. This is due to distance limitations on the very high speed BLCN system. Reliability in the FLAN will require redundant data links, but simultaneous use of data links is not necessary to achieve higher data rates. The capacity need of the FLAN will be 2 Mbps for the customer work station complex, plus 2 Mbps to support any "background" data processing equipment that may be attached. In addition, the modular expansion of the work station complex

should be accommodated within a radius of 2500 feet. This is reflected in the specifications on the "background" design. These needs establish the following requirement:

> F-R3: The FLAN, idependent of the data rates of attached equipment, shall sustain on an as needed basis, with low delay, a transmission capacity of 4 Mbps, at distances up to 5000 feet.

Through the 1980's and 1990's, SPLICE applications are anticipated to grow in the foreground work station complex. This makes increased data rates and distances desirable for expansion of the SPLICE system. Presently only data communications is needed, however the capacity to integrate video and or voice capabilities to support customer business activities is considered desirable. This leads to the identification of the following capacity related evaluation criteria:

> F-C1: A data rate capacity and distance capability greater than requirement F-R3 is considered desirable.

> F-C2: The capacity to expand communications services to include business oriented video and voice communications on the FLAN is considered desirable.

### 2. FLAN Connectivity Needs

The FLAN will support connections for supply customer work stations and periperal equipment. The network must be versatile in its ability to provide connections at work locations of the customers. In addition, connections must be easily reconfigured and expanded to meet growing needs of the users. This versatility must support varied

configurations at 62 SPLICE locations that have a wide range of facility arrangements. SPLICE project specifications do not identify the number of work stations that must be connected to the FLAN. However, the current ratio of background computers to customer terminals is approximately 1:20 [Ref. 2]. The maximum number of background computers at a SPLICE configuration will range from a low of none, to a high of 17 to 22 in the next 11 years. Larger configurations in the system will have an assortment of approximately 15 background computers [Ref. 14]. Based on these figures, the FLAN should be able to support 300 physical connections. This generates a requirement:

> F-R4: The FLAN shall provide a minimum of 300 physical connections for data processing equipment.

Connectivity is of major importance in providing an adaptable communications service to the customer. The following evaluation criteria should be considered for that adaptibility:

> F-C3: The capability to make connections in excess of the requirement F-R4 is desirable.

### 3. FLAN Reliability Needs

The FLAN must provide a fault tolerant data communications service. The customer's work station will be a primary tool for conducting supply business. The availability of the work stations and the ability to communicate information will be essential in the conduct of supply operations. The FLAN to maintain a reliable and available communications service must be immune to single point failures, data link failures, and must continue to function during on-line maintenance. In order to support this reliability the requirements are:

F-R5: The FLAN will provide more than one data communications path between each pair of equipment interfaces.

F-R6: The FLAN will not depend on the operational status of any attached equipment. The FLAN will operate as an independent stand alone facility.

### 4. Additional FLAN Needs

In order to further evaluate local area network products that meet FLAN evaluation requirements, additional evaluation criteria are needed to identify example networks that have a potential for meeting SPLICE design needs. This will aid in evaluating and identifying example off-the-shelf products with architectures that can meaningfully support the SPLICE system over its life cycle. The additional evaluation criteria are:

F-C4: The vendors capability to provide a variety of off-the-shelf data processing equipment interfaces is desirable.

F-C5: Compatibility with local area network standards such as those supported by the IEEE 802 Project is desirable.

# IV. THE EVALUATION PROCESS

## A. BLCN EVALUATION PROCESS

### 1. BLCN Needs

The evaluation process for the Background Local Computer Network (BLCN) has the strategy of providing data communications sevice for mainframe computers. This service must have a very high capacity and high reliability to support batch processing and large data base management processing operations. The BLCN will be important in improving the performance of exsisting host computers and extending their useful life. The requirements that must be met by the local area network architectures identified for the BLCN are:

B-R1: An off-the-shelf architecture.

B-R2: A datagram and virtual circuit decentralized controlled message service.

B-R3: Data rate of 50 Mbps with minimum of 25 Mbps over a distance of 1000 feet.

B-R4: Connect 32 equipments in a radius of 500 feet.

B-R5: Redundant data links.

B-R6: Network immune to single point failures.

The major requirement in this evaluation process is the capacity requirement B-R3. This requirement is generated by the need to sustain large file processing for batch and data base management in the background host computer complex. This data rate is much higher than interactive processing data rates of 1 to 10 Mbps supported by local area networks architectures used in business environments. The requirement serves to focus the evaluation process on a specific vendor product which is used as an example of the desired architecture.

### 2. EICN Example Architecture

Hyperchannel from Network Systems Corporation (NSC) is an example of a local area network architecture that can satisfy EICN requirements. NSC's Hyperchannel was introduced in 1977 to provide a high capacity network service for data center type operations. Hyperchannel employs a datagram service on a bus consisting of up to four baseband coaxial cables. Data link access is controlled by adaptors that employ CSMA with an acknowledgement for collision detection. In addition, the access method also supports a priority access scheme. The multiple bus configuration supports a data rate of 50 Mbps over distances up to 3000 feet. A data link failure will lower the data rate, but not below 25 Mbps, if at least two cables are used. Microprocessor based adaptors are used to make equipment connections to multiple buses. The network can support up to 256 physical connections.

The following provides an overview of Hyperchannel's attributes on each evaluation criteria.

> Evaluation criteria B-C1: 25-50 Mbps data rate in excess of 1000 feet.

Hyperchannel sustains the data rate up to 3000 feet.

Evaluation criteria B-C2: Connect 32 devices in a radius in excess of 500 feet.

Hyperchannel can provide connections for 256 devices over a distance of 3000 feet (radius 1500 feet). In addition, a 2400 foot coaxial cable, 10 Mbps, Hyperbus local area network can be interfaced to Hyperchannel adaptors. The Hyperbus would be an alternative means to connect background host equipment if they cannot be located in the 1500 foot radius of Hyperchannel.

Evaluation criteria B-C3: Capability to provide off-the-shelf interfaces to SPLICE background host computers.

Hyperchannel provides over 20 processor adaptor types each compatible to a different vendor computer. All SPLICE host computers have adaptors except the Burroughs Medium System and Tandem computers.

Evaluation criteria B-C4: Standards compatibility.

Hyperchannel is not compatible with any of IEEE Project 802 committee's recommended standards.

## B. FLAN EVALUATION PROCESS

### 1. FLAN Needs

The evaluation process for the Foreground Local Area Network (FLAN) has a strategy that focuses on a communications service adaptible to the growing and changing needs of SPLICE customers. This is to insure that customer needs can be met with network performance in terms of capacity, connectivity, and reliability. The evaluation requirements that must be met by the FLAN are:

F-R1: An off-the-shelf architecture.

F-R2: Datagram and virtual circuit distributed controlled message service.

F-R3: Data rate of 4 Mbps over a distance of 5000 feet.

F-R4: 300 physical connections.

F-R5: Redundant data links.

F-R6: Network immune to single point failures.

Evaluation of off-the-shelf architectures in meeting FLAN requirements will generally focus on local area network classifications developed in Chapter 2. Requirement F-R2 is typical of all off-the-shelf local area network architectures. The capacity requirement of 4 Mbps will rule out architectures utilizing twisted pair wiring for a transmission medium.

The connectivity requirement (F-R4) for 300 physical connections generally rules out networks which use a physical ring topology. Products with a ring topology support only 32 to 255 connections. These architectures utilize point-to-point transmissions between ring connections. This technology provides for effective use of the transmission medium to achieve high data rates and network distance spans. However, the ability to make physical connections is reduced even if node controllers or interface units used to support multiple devices in the proximity of the connection. This reduces the flexibility of the connectivity service, the ability to add nodes between nodes. In addition, reliability of ring topology networks depends on an active string of repeaters. A node failure will down the system in some implementations. Based on connectivity and reliability

needs, local area network architectures with a ring topology do not appear to be advantageous for SPLICE.

The bus topology categories of architectures remains for consideration. The token bus architectures have a typically low data rate, 1 to 2.5 Mbps, which cannot meet the F-R3 capacity rate of 4 Mbps. This access method has a deterministic delay, and can give stations a priority for access, but these features are not FLAN needs. However, the data capacity of the transmission medium is not effectively used with these features. In addition, polling schemes using a token have limited the number of physical connections to less than 256. Hence, these architectures are unable to meet the connectivity requirement, F-R4. The inability of token bus architectures to meet requirements F-R3 and F-R4 does not appear to be advantageous for SPLICE.

Evaluation requirements at this stage have narrowed the local area network categories for consideration to those architectures with a coaxial cable transmission medium, and CSMA/CD access methods with a bus topology. Due to their bus topology, these architectures fulfill the reliability requirement F-R6, for no single point failure. Baseband coaxial cable CSMA/CD architectures do not completely meet the redundant data link requirement, F-R5. Therefore, they do not appear advantageous for SPLICE and are eliminated from consideration.

The local area network architectural category remaining includes products with a broadband coaxial cable transmission medium and a CSMA/CD access method with a bus topology. An important feature of these broadband architectures is that redundant cable configurations are easily implemented. Cable splitters are used to connect interface units to redundant trunk cables. Examples of local area networks in this architectural category are:

- Localnet by Sytek Inc.
- Net/One (broadband) by Ungermann-Bass, Inc.
- Wangnet by Wang Laboratories, Inc.

### 2. Evaluation of FLAN Example Architectures

The FLAN example network architectures meet the mandatory requirements needed for the SPLICE project. In continuing the evaluation process, the attributes of these architectures must be evaluated using the FLAN evaluation criteria. The FLAN evaluation criteria briefly are:

F-C1: Data rate in excess of 4 Mbps and/or a distance span greater than 5000 feet.

F-C2: Capability to provide video and/or voice services.

F-C3: Capability to support more than 300 physical connections.

F-C4: Availability of off-the-shelf interfaces.

F-C5: Compatibility with standards

F-C6: Vendor experience with networks for business organizations.

### 3. FLAN Example Architectures

#### a. CSMA/CD Broadband Architectures Considered

Wangnet, by Wang, uses a dual cable frequency allocation scheme. This implementation is incompatible with IEEE Project 802's single cable TR 40.1 broadband standard.

Conformity with this standard is important in retaining flexibility in the evaluation of RF modems to meet present and future needs. Presently, the Wang product is incompatible with other vendor modems except by special interface techniques [Ref. 12]. The dual cable implementation also requires the installation of four cables in order to have redundant data paths. This complicates installation and creates an inordinate amount of cabling, a cable maze that local area networks are intended to eliminate [Ref. 16]. The "wang band" is the primary 12 Mbps channel for Wangnet. It is designed to provide communications for only Wang computers and equipment [Ref. 17].

Localnet, by Sytek Inc., has a low single channel capacity, limited available interfaces, and a variation from broadband standards. Localnet's System 40 supports 5 RF channels with a 2 Mbps data rate on each channel, for a total data rate of 10 Mbps. However, a 4 Mbps single channel capacity would be more desireable in meeting FLAN needs. Equipment interfaces are supported by two systems. Localnet's System 40 supports only parallel interfaces of the VAX PDP-11 and Intel-compatible bus architectures. Low speed serial interfaces, RS-232C, are handled by Localnet's System 20. The two systems are connected by Localnet's 40/20 bridge. The Sytek broadband network uses a single cable midsplit channel allocation scheme, however, frequency allocations are offset from IEEE Project 802's TR 40.1 standard [Ref. 12].

### b. FLAN Evaluation Process Example

Broadband Net/One by Ungermann-Bass, Inc., is an example of a local area network architecture which meets FLAN evaluation requirements and criteria. Broadband Net/One offers a high single channel data rate capacity, a wide range of off-the-shelf equipment interfaces, and it

adheres to the IEEE Project 802 TR 40.1 standards. In order to highlight broadband Net/One's architecture, a review of the networks performance attributes within the framework of FLAN evaluation requirements and criteria is provided.

### General Attributes

Requirement F-R1: An off-the-shelf architecture.

Requirement F-R2: A datagram and virtual circuit distributed controlled message service.

Broadband Net/One was introduced by Ungermann-Bass in July 1982. The system uses a CSMA access method for distributed control of a datagram service. In addition, Net/One can also support a virtual circuit service.

### Capacity Attributes.

Requirement F-R3: Data rate of 4 Mbps over a distance of 5000 feet.

Criteria F-C1: Data Rate in excess of 4 Mbps and/or distance span greater than 5000 feet.

Criteria F-C2: Capability to facilitate video and voice services.

Broadband Net/One supports a cable network up to 50,000 feet in length. It provides a 5 Mbps data rate on any of five 6MHz channels for a total network capacity of 25 Mbps. The RF modems can support simultaneous use of the network for video and voice services.

### Connectivity Attributes

Requirement F-R4: 300 physical connections

Criteria F-C3: Capability to make more than 300 connections.

Broadband Net/One can connect up to 300 Network Interface Units (NIU) to each of five (5) RF channels. Each NIU can support up to 24 user devices.

### Reliability Attributes

Requirement F-R5: Redundant data links.

Requirement F-R6: Network immune to single point failure.

Broadband Net/One may utilize broadband splitters and couplers to make NIU connections to redundant cable configurations. Distributed access control methods implemented by NIUs make network immune to failure of attached equipments.

### Other Criteria

Criteria F-C4: Availability of off-the-shelf interfaces.

Broadband Net/One utilizes Network Interface Units (NIU) which contain modem interface units for use with RF modems. With that exception, the NIUs are virtually identical to NIUs used with the baseband Net/One local area network. NIUs are designed with a Z-80 processor and are user programmable to enable the customer to attach any device. NIUs are compatible with the following vendor equipment:

> Burroughs, Digital Equipment Corporation, Honeywell, IBM, NCR, Sperry Univac, OEM, PDP, Zilog, Onyx, Hewlett Packard, Data General, Xerox, and Sytek. [Ref. 18] [Ref. 19]

In addition, NIUs offer the following electrical interfaces:

> IEEE 488, RS-232C, RS-449, TTL, CATV, and 8/16/32 bit parallel.

Broadband Net/One NIUs are designed to give the network system hardware independence.

Criteria F-C5: Standards compatibility.

Broadband Net/One adheres to the IEEE Project 802 TR 40.1 broadband standard. In addition, broadband Net/One has gateways to baseband Net/One which is compatible with the IEEE Ethernet standard.

Broadband Net/One is an example of an off-the-shelf CSMA bus architecture that meets SPLICE design needs.

# V. CONCLUSION

The strategy for evaluating local area networks for SPLICE consisted of three phases.

The first phase developed a performance classification system for local area network architectures. Network architectures were classified based on two schemes. The first scheme was the transmission medium used in the physical layer of the architectures. The second scheme was the access method, and related network topology, used in the data link layer of the architectures. Performance attributes of each class of architecture were identified within the general performance areas of capacity, connectivity, and reliability. Using this classification system, over 25 local area network products were classified based on their architectures. This identified architectural classes of network products with related performance capabilities. This performance classification system provides an adaptable framework to easily classify present and future network products and architectures. With this system, the performance of network products and architectures can be easily evaluated.

The second phase of the evaluation strategy reviewed the distributed system design concepts being built around local area networks for SPLICE. Based on the system design, the need for two local area networks was established. They were a Background Local Computer Network (BLCN) and a Foreground Local Area Network (FLAN). The design needs of each network were translated into a set of evaluation requirements and criteria. These evaluation guidelines were primarily developed by identifying the performance needs of the networks in terms of capacity, connectivity, and

reliability. In addition, evaluation guidelines identified other functional design needs of the network systems.

In the third phase, the evaluation process was executed. This was accomplished by mapping requirements against the performance related classes of architectures developed in phase one. The evaluation process for the BLCN was driven by very high capacity and high reliability requirements. Hyperchannel, a baseband CSMA-bus network architecture by Network Systems Corporation, is an example of an architecture which satisfied the evaluation requirements and criteria for the BLCN. The evaluation process for the FLAN identified three example products with broadband CSMA-bus architectures which met requirements. Broadband Net/One by Ungermann-Bass was an example of an architecture that satisfies FLAN evaluation criteria.

This research describes a strategy for evaluating local area network architectures for the SPLICE project. It is hoped that this will assist the SPLICE project aquisition process in evaluating the local area network architectures. In addition, it provides a methodology and strategy that others may use in their evaluation of local area network architectures.

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